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SPD-502

# OPERATING MANUAL

FOR THE

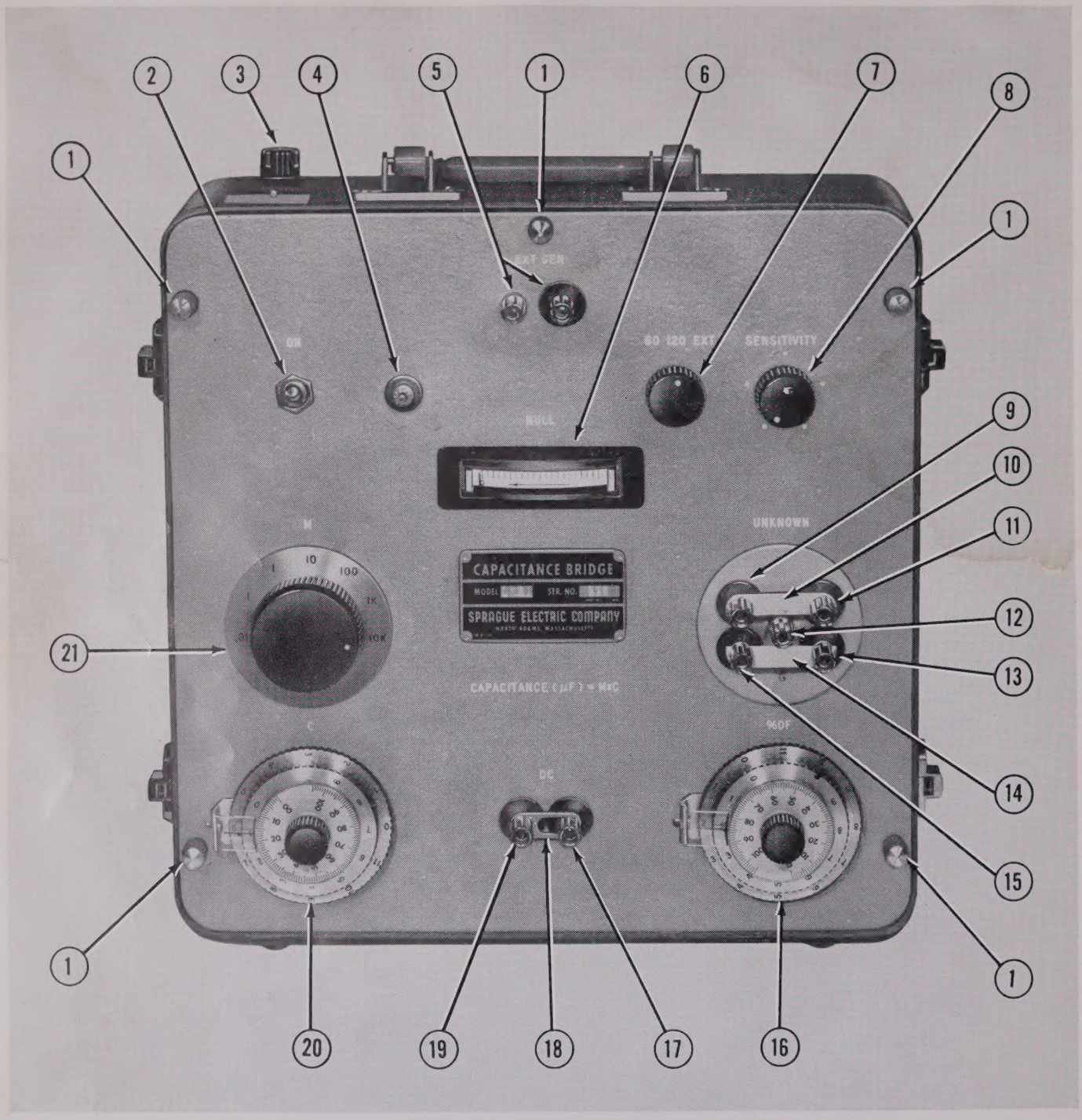
# MODEL 1W2A

# CAPACITANCE BRIDGE

• • •

SPRAGUE ELECTRIC COMPANY

North Adams, Massachusetts




1. *Front panel mounting screw*
2. *On-Off switch*
3. *Fuse*
4. *Pilot light*
5. *External Generator terminals*
6. *Null meter*
7. *Frequency switch*
8. *Sensitivity control*
9. *Red I terminal*
10. *Shorting link*
11. *Red E terminal*
12. *Ground terminal*
13. *Black E terminal*
14. *Shorting link*
15. *Black I terminal*
16. *%DF control*
17. *Black (negative) DC terminal*
18. *DC shorting link*
19. *Red (positive) DC terminal*
20. *C control*
21. *M control*

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# Operating Manual for the Model 1W2A Bridge

## 1. Introduction

**1.1 General.** The Model 1W2A Bridge is a precision capacitance bridge that offers the high accuracy necessary for laboratory work as well as the simplicity and speed of operation required for production testing.

**1.2 Operating Frequency.** The Model 1W2A Bridge utilizes self-contained generators and a tuned amplifier-null detector for operation at either 60 cps or 120 cps. In addition, the Model 1W2A has provision for connecting an external generator to allow operation at any frequency from 50–1600 cps. (When an external generator is employed, the Model 1W2A's self-contained amplifier-null detector is untuned.)

**1.3 Standard Mode.** Because 120 cps operation is the mode used most often, the % *DF* control is direct-reading at that frequency. At all other frequencies, the actual dissipation factor may be found by computing the relation of the operating frequency to 120, and applying that same relation to the dial reading of the % DF control. (See paragraph 4.9.) The *C* control dial is direct-reading at all operating frequencies; the *M* control is likewise unaffected by frequency changes.

**1.4 Application.** Although designed primarily for the measurement of electrolytic capacitors, the Model 1W2A may be used to measure any type capacitor whose capacitance and dissipation factor fall within its ranges. The capacitance range is from 0 to 120,000 $\mu$F.* The dissipation factor range, at 120 cps, is from 0 to 120%, with provision for extending the upper limit when an external resistor is used. The upper limit for 120 cps operation is 1000%; for all other frequencies the practical upper limit is 500%.** (See paragraph 7.)

**1.5 Specifications.** Performance specifications and other data pertaining to the Model 1W2A Bridge are given in the appendix.

**1.6 Polarizing Voltage.** Because the Model 1W2A is a very low voltage bridge, it is usually unnecessary to apply a d-c polarizing voltage to the capacitor under test. Paragraph 6 details the procedure to follow when d-c polarizing voltage is desired.

**1.7 Schematics.** Partial schematics of circuits being discussed are shown with the text related to them. A complete schematic of the Model 1W2A Bridge is shown in figure 14 on page 12.

*When the operating frequency is higher than 120 cps, the *practical* upper limit of the capacitance range, in microfarads, is determined by the formula: $120{,}000 \times \frac{120}{f}$

**To find what the practical upper limit of dissipation factor will be in dial reading, divide the operating frequency into 60,000. The formula is: %*DF* dial reading $= \frac{60{,}000}{f}$

## 2. Basic Circuits

**2.1** The 1W2A Bridge circuitry consists of the generator circuit, the bridge circuit, and the detector circuit.

**2.2 Generator Circuit.** The front-panel frequency switch, Switch $S_3$, determines whether the frequency applied to the bridge is 120 cps, 60 cps, or a frequency supplied by an external generator.

*a.* In 120 cps operation, the a-c input frequency is doubled by a frequency converter (fig. 1) which consists of a full-wave, unfiltered, bridge rectifier with a series resonant circuit in its output tuned to 120 cps.

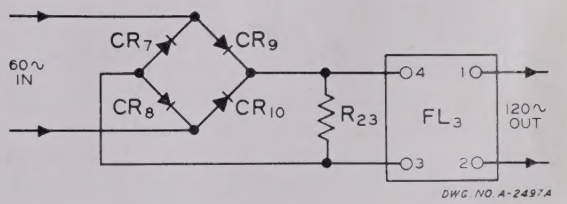


Figure 1. 120 cps generator circuit.

*b.* In 60 cps operation, the signal frequency is derived from the a-c source; it is taken from the secondary of the power supply transformer ($T_1$, fig. 14) and applied directly to the primary of the bridge transformer ($T_2$, fig. 2).

*c.* For external operation, Switch $S_3$ connects the primary of the bridge transformer directly to the *Ext Gen* binding posts. If the Model 1W2A Bridge is to perform within specifications over its entire range, the external generator must have an output with these characteristics: 35 volts, 250 ohms, and not more than 1% harmonic distortion.

*NOTE. A generator with lower output voltage and/or higher output impedance will not affect instrument accuracy, but there may be a loss of sensitivity in the higher capacitance ranges.*

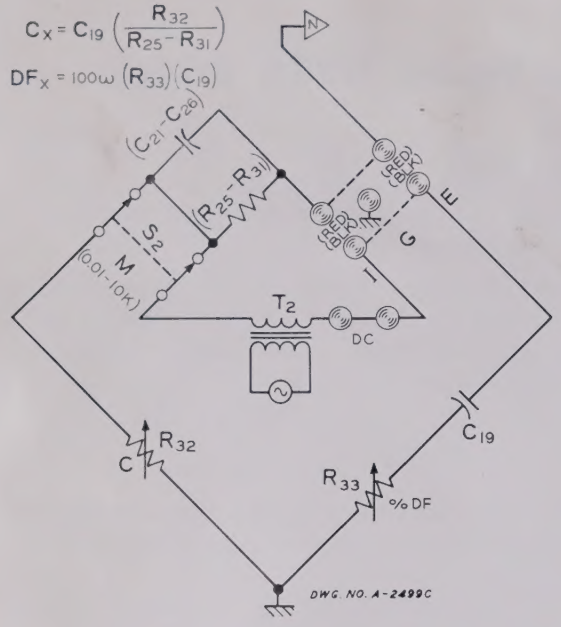


Figure 2. Basic bridge circuit.

**2.3 Bridge Circuit.** The basic bridge circuit (fig. 2) is an application of the series-resistance capacitance bridge. It measures the equivalent series impedance of the unknown capacitor at whatever frequency is selected by switch $S_3$. In the Model 1W2A, the bridge circuit operates over the frequency range of 50-1600 cps.* Continuously variable resistor $R_{32}$, the *C* control, is a ratio arm that is calibrated directly in microfarads divided by *M*. The *M* control (switch $S_2$) selects the range multiplier resistor. Continuously variable resistor $R_{33}$, the *% DF* control, is in series with the capacitance standard ($C_{19}$). It is direct-reading only at 120 cps operation. (See paragraph 4.9.) Capacitors $C_{21}$ to $C_{26}$ are necessary to compensate for unavoidable residual impedances in the instrument.

**2.4 Detector Circuit.** The basic circuit of the tuned, transistor amplifier-null detector (fig. 3) is an R-C coupled 4-stage audio amplifier; it is made selective to the operating frequency by means of the sharply-tuned bandpass filter ($FL_1$ for 120 cps [illegible] for 60 cps*) between the second and third [illegible]. Non-linear sensitivity, which greatly simplifies operation of the bridge, is obtained by the use of diodes $CR_3$, $CR_4$, $CR_6$, capacitor $C_9$, and resistor $R_{19}$. Zener diodes $Z_1$ and $Z_2$ and resistor $R_1$ limit input surges when d-c polarizing voltages are used. Diode $CR_5$ is the meter rectifier. Meter $M_1$, the *Null* meter, is a galvanometer that indicates bridge balance. The negative d-c voltages for operating the detector transistors are provided by a full wave, filtered, power supply (fig. 4).

*When the *M* control is set at the *.01* position, the practical upper frequency limit is reduced to 400 cps.

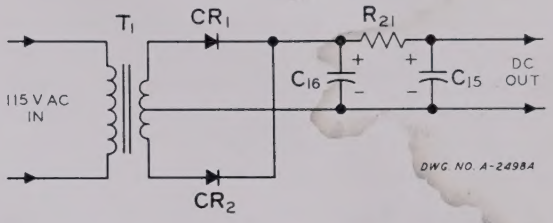


Figure 4. Detector power supply.

## 3. Input Connections

**3.1** The capacitor under test can be attached to the Model 1W2A Bridge by either a 2-, 3-, or 4-terminal connection. The choice depends upon the capacitance rating and physical construction of the unknown capacitor. As a rule, the 2-terminal connection is used for capacitance values between 1 $\mu$F and 1000 $\mu$F; the 3-terminal connection is employed for values below 1$\mu$F; and the 4-terminal connection is necessary for accurate determination of dissipation factor of capacitances above 1000$\mu$F.

**3.2 The 2-Terminal Connection.** The 2-terminal connection (fig. 5*a*) is normally used for medium capacitance values. Technically speaking, the 2-terminal connection is used when the capacitance of the unit under test is high enough to prevent measure-

*No detector filtering is used for those measurements which utilize an external generator.

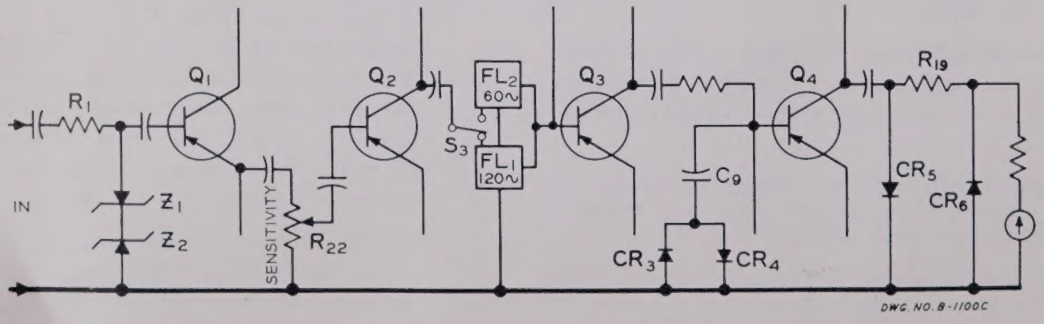


Figure 3. Basic detector circuit (*Simplified*).

ment error due to stray capacitances, and the ESR is high enough to prevent measurement error due to connection resistances. These limits cannot be precisely defined, but in general 2-terminal measurements are satisfactory for capacitance values between 1 $\mu$F and 1000 $\mu$F.

**3.3 The 3-Terminal Connection.** The 3-terminal connection (fig. 5*b*) is most often used for precise measurements of low value (below 1$\mu$F) capacitances because one terminal of the measuring circuit is grounded. The 3-terminal connection is also frequently used for measuring higher capacitance values if the capacitor under test has a floating metallic case that must be grounded to avoid pickup.

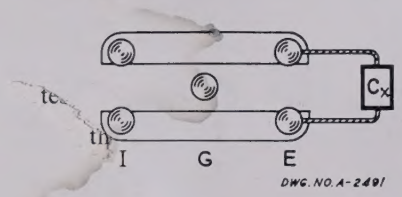


Figure 5a. 2-terminal input connection.

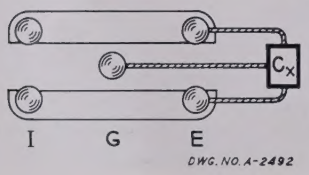


Figure 5b. 3-terminal input connection.

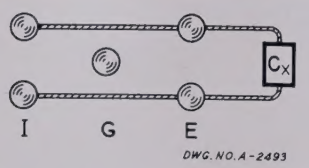


Figure 5c. 4-terminal input connection.

**3.4 The 4-Terminal Connection.** The unique 4-terminal connection (fig. 5*c*) is important for accurate measurements of dissipation factor when the ESR is small. In 2-and 3-terminal DF measurements, serious errors may result from stray connection resistances. The schematic diagram in figure 6 gives a simplified explanation of how the 4-terminal connection differs from the 2-terminal connection.

**3.4.1 Detailed 4-Terminal Theory.** A more detailed explanation of 4-terminal operation follows. (Refer back to figure 2, the bridge circuit.) With 4-terminal input, the connection resistance to the red *I* post is placed in series with the range resistor (selected by $S_2$, the *M* control) and has no effect on DF measurements and only a very slight effect on the accuracy of capacitance measurements. The connection resistance to the black *I* post is placed in series with the bridge transformer (T2) and has no effect on instrument accuracy. The connection resistance to the red *E* post is placed in series with the detector circuit and has no effect on instrument accuracy. The connection resistance to the black *E* post is placed in series with the resistance standard (R 33); it has negligible effect on DF measurements and no effect on capacitance measurements.

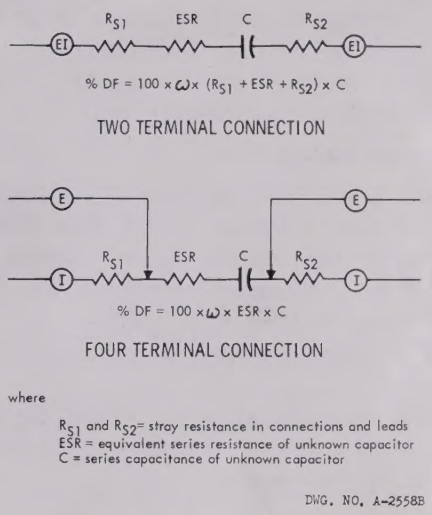


Figure 6. Simplified 4-terminal theory.

**3.5 Stray Capacitance.** Although stray capacitances between the red *Unknown* posts and ground will not affect measurement accuracy, stray capacitances between the black *Unknown* posts and ground do affect bridge measurements. The graph in figure 7 shows the relation between stray capacitance from the black *Unknown* posts to ground (plotted on the vertical

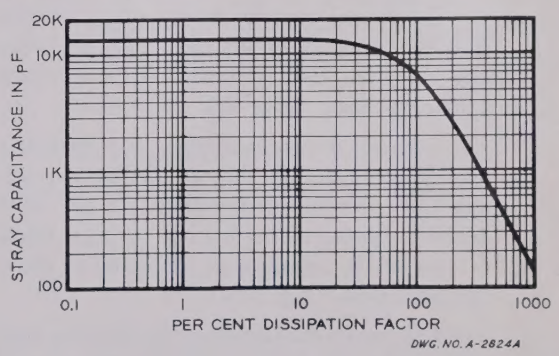


Figure 7. Relationship of stray capacitance and % DF when bridge accuracy is a constant of 1%.

axis) and the $\%DF$ dial reading (plotted on the horizontal axis) when the bridge accuracy is a constant of 1%. For example, if the $\%DF$ control is set at 120%, stray capacitance between ground and the lead of the capacitor going to the black *Unknown* posts may be as high as 5000 pF without affecting the measurement accuracy by more than 1%.

## 4. Operation

**4.1 Connect to Power Source.** With the power cord, which is found mounted in the cover, connect the bridge to a 105-125 volt 60 cps outlet. If the a-c outlet does not have a mating receptacle for the 3-conductor plug, use the three-to-two adapter that comes with the power cord.

*NOTE. Whether the outlet is 2-conductor or 3-conductor, a good ground connection is essential — either to the short wire of the adapter, or to the U-shaped grounding prong of the power cord plug.*

**4.2 Prepare Binding Posts.**

*a.* For 2- and 3-terminal operation, connect the two black *Unknown* binding posts with one shorting link; join the two red *Unknown* binding posts with the other shorting link. Screw the binding posts down tightly.

*b.* For 4-terminal operation, remove the shorting links.

*c.* For normal operation (*i.e.*, without d-c polarization), connect the *DC* shorting link between the *DC* binding posts.

**4.3 Select Frequency.** Set the frequency switch for 60 cps, 120 cps, or external generator operation. (If an external generator is used, make certain it has the output characteristics given in paragraph 2.2*c*; remember that the left *Ext Gen* post is grounded.)

**4.4 Apply Power.** Turn the power switch *on*. The bridge is now ready for immediate use.

**4.5 Attach Unknown Capacitor.** Connect the capacitor under test to the *Unknown* binding posts (fig. 5).

*a.* For 2-terminal measurements, one capacitor lead is connected to the red *Unknown* posts, and the other lead is connected to the black *Unknown* posts. (fig. 5*a*).

*b.* For 3-terminal measurements, one capacitor lead is connected to the red *Unknown* posts, and the other lead is connected to the black *Unknown* posts. The floating metallic shield or case of the capacitor is connected to the *G* (ground) post. (fig. 5*b*).

*c.* For 4-terminal measurements, the shorting links between the red and black binding posts are removed. One capacitor lead is connected to the red *E* and *I* posts, while the other lead is connected to the black *E* and *I* posts. If the unknown capacitor has long leads, it may be attached as shown in the diagram of figure *5c* and the photograph in figure *8a*. If the capacitor under test should have short leads or stub-type terminals, or is at a distance from the bridge, connect it to the bridge with a set of paired, insulated, extension leads. (fig. *8b*) The two leads in pair must not touch each other where they connect to the capacitor. For convenience, the extension leads may terminate in spring clip jaws that are insulated from each other. (This is the type illustrated in figure *8b*.)

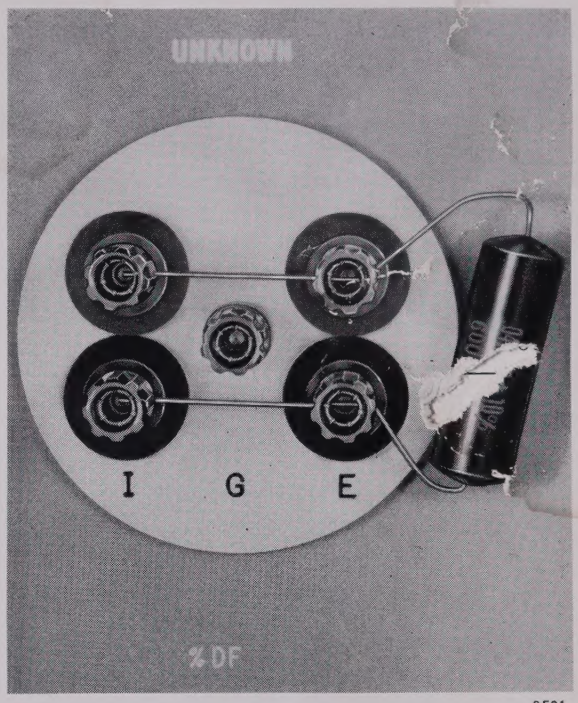


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Figure 8a. Direct 4-terminal connection.

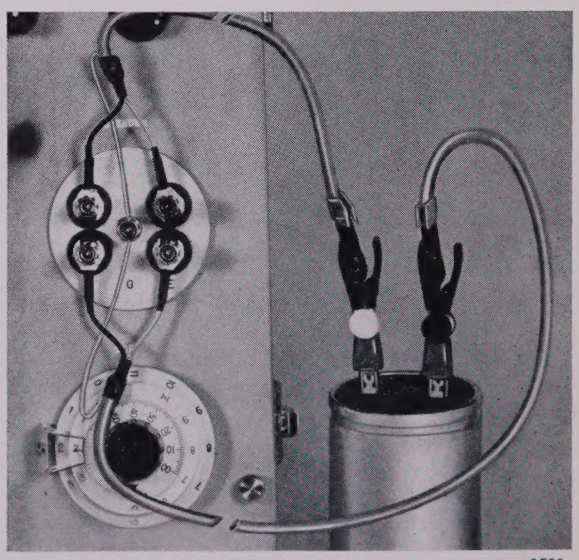

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Figure 8b. Remote 4-terminal connection.

**4.6 Balance Bridge (Nominal Value Known)**

*a.* If the nominal value of the capacitor under test is known, set the *M* control to the appropriate range and adjust the *Sensitivity* control for an on-scale reading. Then alternately adjust the

*C* and % *DF* controls until the *Null* meter reading is minimum.

*NOTE. The further the Sensitivity control is advanced clockwise, the greater the resolution obtainable.*

*b.* If, at balance, the *C* control reads less than *1.000*, turn the *M* control to the next lower setting and rebalance the bridge. This will afford greater readability.

*c.* If, at balance, the *C* control is set to greater than *10.000*, turn the *M* control to the next higher setting and rebalance the bridge. This will afford greater sensitivity.

**4.7 Balance Bridge (Nominal Value Not Known)**

*a.* When the nominal value of the capacitor under test is not known, set the *C* control to *3.000*.

*b.* Set the %*DF* control to *00.00*.

*c.* Turn the *Sensitivity* control fully clockwise. If the *Null* meter reading is to the right of mid-scale, turn the control counter-clockwise until the *Null* meter reading is reduced one minor scale division from its maximum point.

*d.* Turn the *M* control for minimum *Null* meter deflection.

*e.* Alternately adjust the *C* and %*DF* controls, as in paragraph 4.5, until the *Null* meter reading is minimum.

*NOTE. When the instrument is used with an external generator, the* Null *meter deflection at balance may be greater than with self-contained operation.*

**4.8 Compute Capacitance.** After the minimum *Null* meter deflection has been obtained, determine the capacitance of the unknown capacitor by multiplying the *C* control dial reading by the *M* control setting.

| Example: | *Control* | *Dial Reading* |
|---|---|---|
| | *C* | *2.637* |
| | *M* | *10* |

$C_X = 2.637 \times 10$, or 26.37 $\mu$F

**4.9 Compute Dissipation Factor.** When minimum *Null* meter deflection is obtained, the dissipation factor of the unknown capacitor is equal to the % *DF* dial reading x $\frac{f}{120}$.

| Example: | *f* | % *DF Dial Reading* | *Dissipation Factor* |
|---|---|---|---|
| | 60 cps | 5.18 | 2.59% |
| | 120 cps | 5.18 | 5.18% |
| | 1600 cps | 5.18 | 69.06% |

*NOTE. Remember that for 120 cps operation the* %DF *control is direct-reading.*

## 5. Corrections for 4-Terminal Operation

**5.1** Errors in dissipation factor measurement are effectively eliminated by 4-terminal operation, but connection and lead resistances to the red *I* post may cause small errors in *capacitance* measurements. If it can be assumed that these stray resistances are less than 0.1Ω, as is usually the case, measurement errors are negligible in all ranges except the two highest ranges, when the *M* control is set at *1K* or *10K*. For the most accurate capacitance measurements, a correction factor must be computed to adjust the capacitance readings in these ranges.

**5.2** One procedure for determining the correction factor is given below.

*a.* Connect a capacitor rated at 10,000$\mu$F ±10% to the bridge using the 4-terminal connection.

*b.* Set the *M* control to *1K*. Then balance the bridge and compute the capacitance (multiplying the *C* dial reading by the *M* setting, as explained in paragraph 4). Record the result as value "B".

*c.* Turn the *M* control to *10K* and balance the bridge again. Record this capacitance reading as value "C".

*d.* The correction factor for an unknown capacitor when the *M* control is set at *1K* is found by multiplying the bridge reading by $\left(\frac{10B-C}{9B}\right)$,

where "B" and "C" are the values computed above. The formula is:

$$C_X \text{ (in } \mu F) = (C \times M) \times \left(\frac{10B-C}{9B}\right)$$

*e.* The correction factor for an unknown capacitor when the *M* control is set at *10K* is found by multiplying the bridge reading by $\left(\frac{10B-C}{9C}\right)$.

The formula is:

$$C_X \text{ (in } \mu F) = (C \times M) \times \left(\frac{10B-C}{9C}\right)$$

## 6. Polarizing Voltages

**6.1** A d-c polarizing voltage is not normally needed with the Model 1W2A Bridge because never more than 0.7 volt, and usually no more than 0.5 volt, is applied across capacitors under test. In those few instances where a polarizing voltage is desired, the preferred source is a wet cell or dry cell.

**6.2** Figure 9 demonstrates the recommended way of applying a polarizing voltage. When polarizing voltages are required, follow these instructions:

*a.* Remove the shorting link from the *DC* posts and connect a d-c power supply to these posts,

observing polarity. (If the unit under test is a polar capacitor, polarity must also be observed in connecting it to the *Unknown* binding posts.)

*b.* Balance the bridge as instructed in paragraph 4.

*c.* The maximum d-c polarizing voltage that may be applied to the Model 1W2A Bridge is 600 volts. The maximum current permissible is determined by the *M* control setting. Follow this table:

| Setting of *M* Control | Maximum current permissible (in mA) |
|---|---|
| *.01* | 2.5 |
| *.1* | 8 |
| *1* | 25 |
| *10* | 80 |
| *100* | 200 |
| *1K* | 400 |
| *10K* | 1000 |

*d.* Since the d-c power supply output is in series with the bridge generator, the a-c impedance of the power supply output must be as low as possible, in order to retain detector sensitivity. This can usually be done by connecting a capacitor of at least the nominal capacitance and voltage rating as the unknown capacitor to the *DC* posts, in parallel with the power supply. Because both *DC* posts are floating, each side of the power supply output must be well isolated from ground. An isolated battery is recommended for the power supply, since most a-c operated d-c power supplies do not have sufficient isolation from the a-c line.

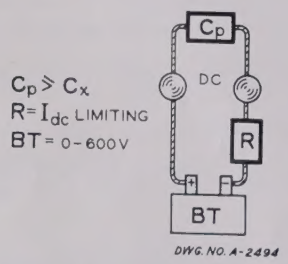



Figure 9. Application of polarizing voltage.

## 7. High DF Measurements

**7.1 General.** The normal dissipation factor range of the Model 1W2A Bridge, at 120 cps, is 0 to 120%. But by using an external resistor, the upper limit of the range may be raised as high as 1000% for 120 cps operation. The range *span*, however, cannot be extended; the range *span* for 120 cps operation is always 120%. Thus, when the upper limit of dissipation factor is raised to 1000%, the lower limit will be raised by an equal amount, or to 880%. (The practical upper limit for all frequencies other than 120 cps is 500%.*)

**7.2 Procedure.** To increase the upper limit of the DF range, proceed these steps:

*a.* Remove the shorting link from the black *Unknown* binding posts.

*b.* Connect the unknown capacitor between the two *I* posts; connect a precision resistor between the black *E* and *I* posts. (fig. 10)

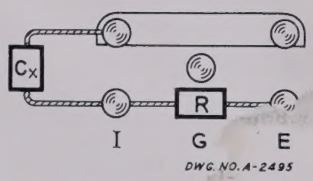



Figure 10. Connection for high DF measurements.

*c.* Compute the value of the precision resistor by this formula:

$R = (DF_{max} - 120) \times 10\Omega$,

where $DF_{max}$ = desired upper limit (expressed in dial reading)

For example:

$DF_{max} = 220\%$ DF

$R = (220 - 120) \times 10$, or—

$= 100 \times 10$, or—

$= 1000\Omega$

**7.3 Bridge Balance.** The normal method of alternately adjusting the *C* and *%DF* controls to balance the bridge cannot be used with high dissipation factors because of the "sliding balance" problem. Follow these steps instead:

*a.* Select the appropriate *M* range.

*b.* Set the *%DF* control to *00.00*.

*c.* Adjust the *C* control for minimum *Null* meter deflection.

*d.* Adjust the *%DF* control for minimum *Null* meter deflection.

*e.* Move the *C* control slightly.

*f.* Dip the *Null* meter with the *%DF* control again and see if the minimum reading this time is lower or higher than the previous one.

*g.* If the reading is lower, move the *C* control again in the same direction. If the reading is higher, move the control in the opposite direction.

*h.* Continue to make small adjustments of the *C* control, dipping the *Null* meter after each adjustment with the *%DF* control.

*i.* Repeat these steps until the minimum deflection is obtained. The bridge is then correctly balanced.

*To find what the practical upper limit of dissipation factor will be in dial reading, divide the operating frequency into 60,000. The formula is: % *DF* dial reading = $\frac{60{,}000}{f}$

## 8. Calibration

**8.1 General.** Although there are several methods of verifying the accuracy of the Model 1W2A Bridge, any calibration procedure should include checking—

*a.* The accuracy and linearity of the *C* control.
*b.* The accuracy and linearity of the *%DF* control.
*c.* The accuracy of the *M* control.

**8.2 Example.** The following procedure is one acceptable method of calibrating the Model 1W2A Bridge. Equipment required for this procedure are:

*a.* Two precision capacitance standards, such as the Sprague No. 280W-series, with nominal values of .01μF and 0.1μF.
*b.* Two precision resistance decades, each covering the range of 1Ω to 10KΩ.

**8.2.1 Calibration of the "C" and "% DF" Controls.**

*a.* Set the *M* control to *.01.*
*b.* Connect the .01μF capacitance standard and one resistance decade, set at 10KΩ, in a series connection between the red and black *Unknown* posts. (fig. 11)
*c.* Balance the bridge.
*d.* At balance, the *C* control reading should be 1.000 ± tolerance.

(Tolerance is 1% + the accuracy of the capacitance standard in % + 10 pF.)

Example:
$C_s$ = .01μF ±0.1%
*C* = 1.000 ±[(1 + 0.1)% + 10 pF] or, clearing—
= 1.000 ±1.2% or, converting—
= 1.000 ±0.012 or, in dial readings—
= *0.988 to 1.012*

*e.* At balance, the *%DF* control reading should be 7.54 ± tolerance.

(Tolerance is 2% + the accuracy of the capacitance standard in % + the accuracy of the resistance standard in %, + 0.1.)

Example:
$C_s$ = .01μF ± 0.1%
$R_s$ = 10KΩ ± .05%
*%DF* = 7.54 ± [(2 + 0.1 + 0.05) % + 0.1] or clearing—
= 7.54 ± [2.15% + 0.1] or, converting—
= 7.54 ± [0.16 + 0.1] or, adding—
= 7.54 ± 0.26 or, in dial readings—
= *7.28 to 7.80*

*NOTE. It is assumed the dissipation factor of the capacitance standard is negligible.*

*f.* Repeat steps *a*, *b*, and *c* with the 0.1μF capacitance standard. Keep the resistance decade set at 10KΩ.

*g.* The nominal *%DF* dial reading is 75.4 for the 0.1 μF standard.

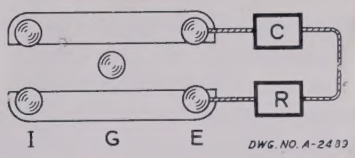



Figure 11. Connection for calibration of C and % D F controls.

**8.2.2 Calibration of the "M" Control.**

*a.* Remove the shorting link from the black *Unknown* posts.
*b.* Connect the first resistance decade between the two *I* posts; connect the second resistance decade between the black *I* post and the *G* (ground) post. (fig. 12)

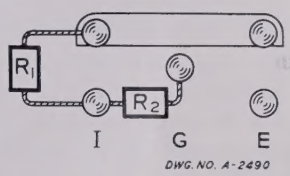



Figure 12. Connection for calibration of M control.

*c.* Set the *M* control to *0.1.*
*d.* Set resistance decade R1 to 10KΩ.
*e.* Set resistance decade R2 to 1KΩ.
*f.* Balance the bridge, using the *C* control only. (The *%DF* control is not in the circuit.)
*g.* At balance, the *C* dial reading should be 1.326 ± tolerance. (Tolerance is 0.5% + the sum of the calibration accuracies of the two resistance decades expressed in %.)
*h.* Repeat steps *c*, *d*, *e*, and *f*, using the control settings given in the table below.
(At balance, the *C* dial reading should continue to be 1.326 ± tolerance.)

| *M* Setting | R1 Setting | R2 Setting |
|---|---|---|
| *1* | 1KΩ | 1KΩ |
| *10* | 100Ω | 1KΩ |
| *100* | 10Ω | 1KΩ |
| *1K* | 1Ω | 1KΩ |
| 10K | 1Ω | 10KΩ |

## 9. Service and Maintenance

**9.1 Preventive Maintenance.** All contact surfaces of the *M* control, *C* control, and *%DF* control should be cleaned and lubricated periodically, depending on the amount of usage. The recommended lubricant is Cramolin compound, manufactured by Caig Laboratories (46 Stanwood Road, New Hyde

Park, L. I., New York, USA). Apply a very light coating of Cramolin to these control surfaces.

**9.2 Malfunctions.** The Model 1W2A Bridge is designed and constructed to give long, trouble-free operation, but occasional malfunctions may occur. Most difficulties can be corrected by using the calibrating instructions contained in this manual and following normal trouble-shooting procedures. Procedures for returning the instrument to the factory are contained in the warranty on the inside back cover.

**9.2.1 Generator Circuit.** To check for proper operation of the generator, take the following steps:

*a.* Remove both shorting links from the *Unknown* binding posts.

*b.* Set the *M* Control to *10K*.

*c.* Measure the voltage between the two *I* posts. With the instrument set for 120 cps operation, the voltage between the two posts should be from .025 — 0.6 volts (rms) at 120 cps ± 0.1 cps with a harmonic distortion of not more than 1%.* For 60 cps operation, the results should be the same, except that the frequency should be 60 cps ±0.1 cps. For external generator operation, the voltage between the two *I* posts should be from .018 — .022 times the voltage applied to the *Ext Gen* terminals, and the frequency should be the same as that of the external generator.

*d.* If results different from these are obtained, begin trouble-shooting procedures.

*Harmonic distortion reading is dependent on reasonably low power source harmonic distortion.

**9.2.2 The 120 cps Tuned Detector Circuit.** To check for proper operation of the 120 cps tuned detector circuit, take the following steps:

*a.* Remove both shorting links from the *Unknown* posts.

*b.* Turn the *Sensitivity* control fully clockwise.

*c.* Set the frequency switch to *120*.

*d.* Apply a 50 μvolt 120-cps signal, obtained from an ungrounded output generator, between the *G* (ground) post and red *E* post. (fig. 13)

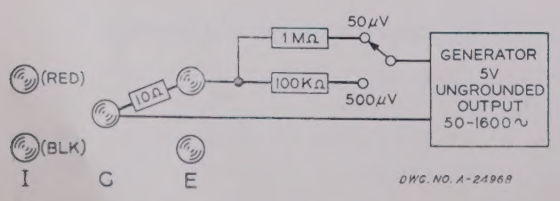



Figure 13. Connection for checking the detector circuit.

*e.* The *Null* meter deflection should be 3 *or more* minor scale divisions from *0*.

*f.* A 500 μvolt 60-cps or 240-cps signal applied in the same manner should cause a meter deflection of *less than* 3 minor scale divisions from *0*.

*g.* If results different from these are obtained, begin trouble-shooting procedures.

**9.2.3 The 60 cps Tuned Detector Circuit.** With the Model 1W2A and test equipment set up as illustrated in figure 13, and following the same general procedures given in the preceding paragraph, the 60 cps. tuned detector circuit may be checked for proper operation as follows:

*a.* Remove the shorting link from the *Unknown* posts; turn the *Sensitivity* control fully clockwise; set the frequency selector switch to *60*.

*b.* Apply a 50 μvolt 60 cps signal, obtained from an ungrounded output generator, between the *G* (ground) post and red *E* post (fig. 13). The *Null* meter deflection should be 3 or more minor scale divisions from *O*.

*c.* The application of a 500 μvolt 30 cps or 120 cps signal should cause a *Null* meter deflection of less than 4 minor scale divisions.

**9.2.4 The Wideband Detector Circuit.** With the Model 1W2A and test equipment set up as described for verification of 120 cps and 60 cps operation (paragraphs 9.2.2 and 9.2.3, above), check for proper operation of the wideband detector circuit by application of a 50 μvolt 50-1600 cps signal. The *Null* meter deflection should be 3 or more minor scale divisions from *O*.

## 10. Useful Formulae

**10.1** The formulae listed below may be useful in the calibration and operation of the Model 1W2A Bridge. Definitions of the terms follow in paragraph 10.2.

*a.* $R \times C = 13.26 \times \%\ DF$ dial reading

*b.* $ESR = \dfrac{13.26 \times \%\ DF}{C}$ dial reading

*c.* $D = .01 \times \%DF$

*d.* $Q = \dfrac{100}{\%\ DF}$

*e.* $PF = \dfrac{\%\ DF}{[1 + .0001\ (\%DF)^2]^{1/2}}$

*f.* $Cp = \dfrac{C}{1 + .0001\ (\%DF)^2}$

*g.* $Rp = R\left[1 + \frac{1}{.0001\ (\%DF)^2}\right]$

*h.* $\theta = \cot^{-1}(-.01 \times \%\ L^{-1})$

**10.2** The following definitions apply to the terms used in the formulae given above:

*a.* C = the equivalent series capacitance of the unknown capacitor, expressed in $\mu$F. (*C* dial reading x *M* control setting)

*b.* R = ESR = the equivalent series resistance of the unknown capacitor, expressed in ohms.

*c.* D = dissipation, expressed as a decimal.

*d.* Q = storage factor, figure of merit.

*e.* PF = power factor, expressed in percent.

*f.* $\theta$ = phase angle.

*g.* Cp = equivalent parallel capacitance of the unknown capacitor, expressed in $\mu$F.

*h.* Rp = equivalent parallel resistance of the uncapacitor, expressed in ohms.

*i.* %DF = percent dissipation factor (dial reading of %*DF* control x $\frac{f}{120}$).

# APPENDIX

# Specifications and Performance Characteristics

## 1. Size

**1.1** 12" wide x 7½" deep x 12" high, including cover.

## 2. Net Weight

**2.1** 20 pounds.

## 3. Mounting

**3.1** The instrument is mounted in an aluminum cabinet, with cover and handle, in standard Sprague blue textured finish. The bridge panel is gray with engraved markings.

## 4. Accessories Supplied

**4.1** Instruments are supplied with a UL-approved 3-wire power cord. The cord's connectors conform to the American Standard for Grounding Type Attachment Plug Caps and Receptacles. A three-to-two wire adapter is also supplied.

## 5. Optional Accessory

**5.1** Available as an accessory is a step-down transformer, Sprague Electric Type 11-9010-2, which has a 230 Vac primary and a 115 Vac secondary. This transformer is specially designed to provide convenient connectors for using the Model 1W2A with 230 Vac, 60 cps power.

## 6. Null Detection

**6.1** A self-contained amplifier-detector and galvanometer are used to indicate bridge balance.

## 7. Generator

**7.1** The 60 cps signal frequency is taken directly from the a-c power source.

**7.2** A self-contained line-driven frequency converter generates the 120 cps signal.

## 8. Capacitance

**8.1 Range:** 0 to 120,000$\mu$F.

**8.2 Accuracy:** ± (1% of reading +10 pF) for self-contained 120 cps operation; ±(2% of reading +10 pF) for all other frequencies.

**8.2.1** If the ambient temperature is maintained at 25 C ±5C and the relative humidity is maintained at 50% or less, a capacitance accuracy of ±(0.5% of reading +10 pF) for 120 cps operation and an accuracy of ±(1% of reading +10 pF) for all other frequencies is possible.

**8.3 Sensitivity:** ±(0.1% of reading + 10pF).

## 9. Dissipation Factor

**9.1 Range:** 0 to 120% DF.

**9.1.1** The upper limit of DF may be extended as high as 1000% with an external resistor.

**9.2 Accuracy:** ±(2% of reading +0.1% DF) for self contained 120 cps operation; ± (2% of reading +0.5% DF) for all other frequencies.

**9.2.1** If the ambient temperature is maintained at 25 C ±5 C and the relative humidity is maintained at 50% or less, a dissipation factor accuracy of ±(1% of reading +0.1% DF) for 120 cps operation and an accuracy of ±(1% of reading +0.5% DF) for all other frequencies is possible.

**9.3 Sensitivity:** ±(0.2% of reading + 0.05 % DF).

## 10. Maximum $C_x$ Conditions

**10.1 A-C:** (For internal generator only.)

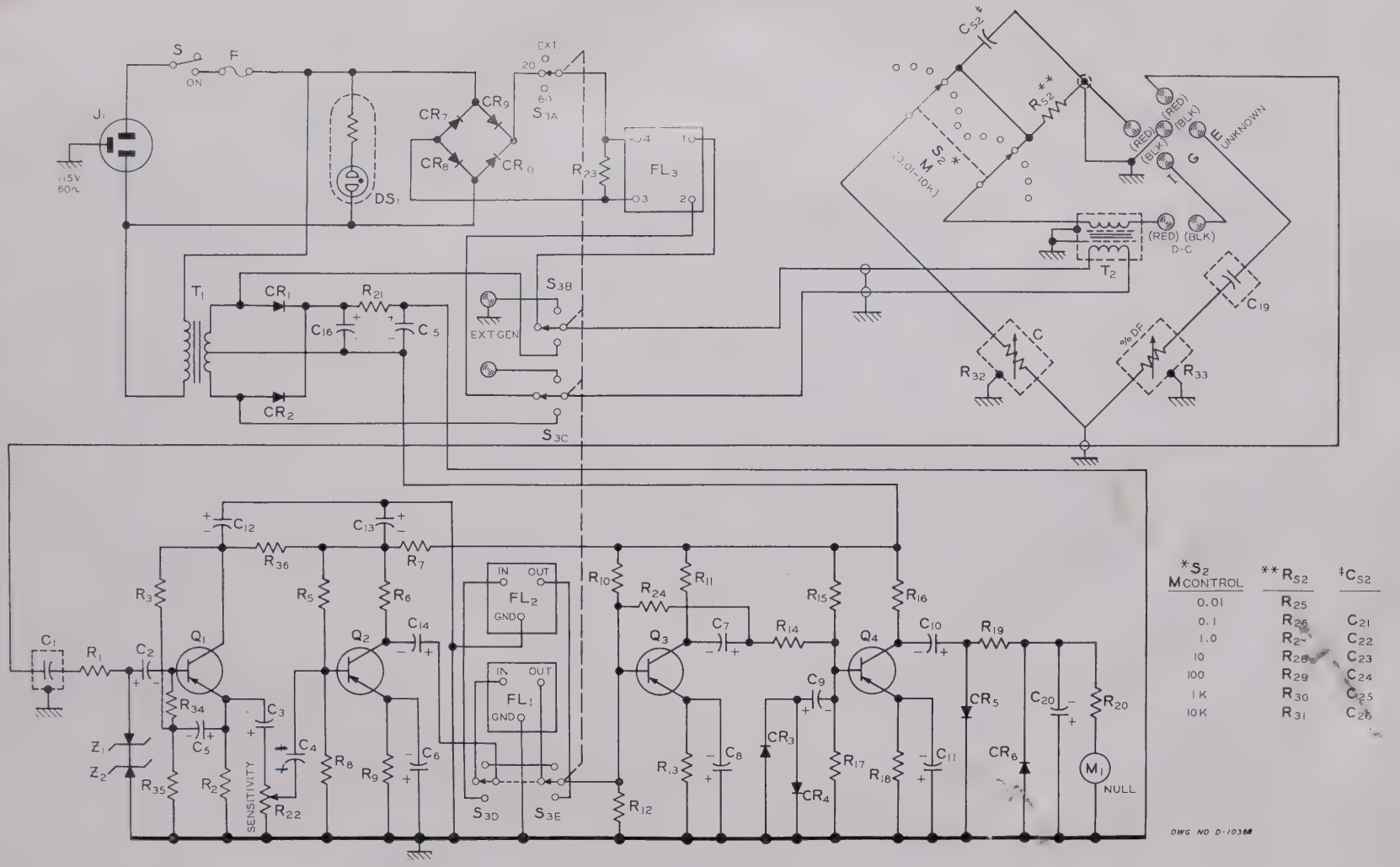
**10.1.1 Frequency:** 60 cps and 120 cps.

**10.1.2 Voltage:** 0.5 volts rms (from 10% to 120% of each decade range); in no case more than 0.7 rms.

**10.1.3 VAR:** 0.75.

**10.1.4 Current:** 1.5 amperes rms.

**10.2 D C:** 0-600 volts (from external source).




| *S2 M CONTROL | **RS2 | ‡CS2 |
|---|---|---|
| 0.01 | R25 | |
| 0.1 | R26 | C21 |
| 1.0 | R27 | C22 |
| 10 | R28 | C23 |
| 100 | R29 | C24 |
| 1K | R30 | C25 |
| 10K | R31 | C26 |

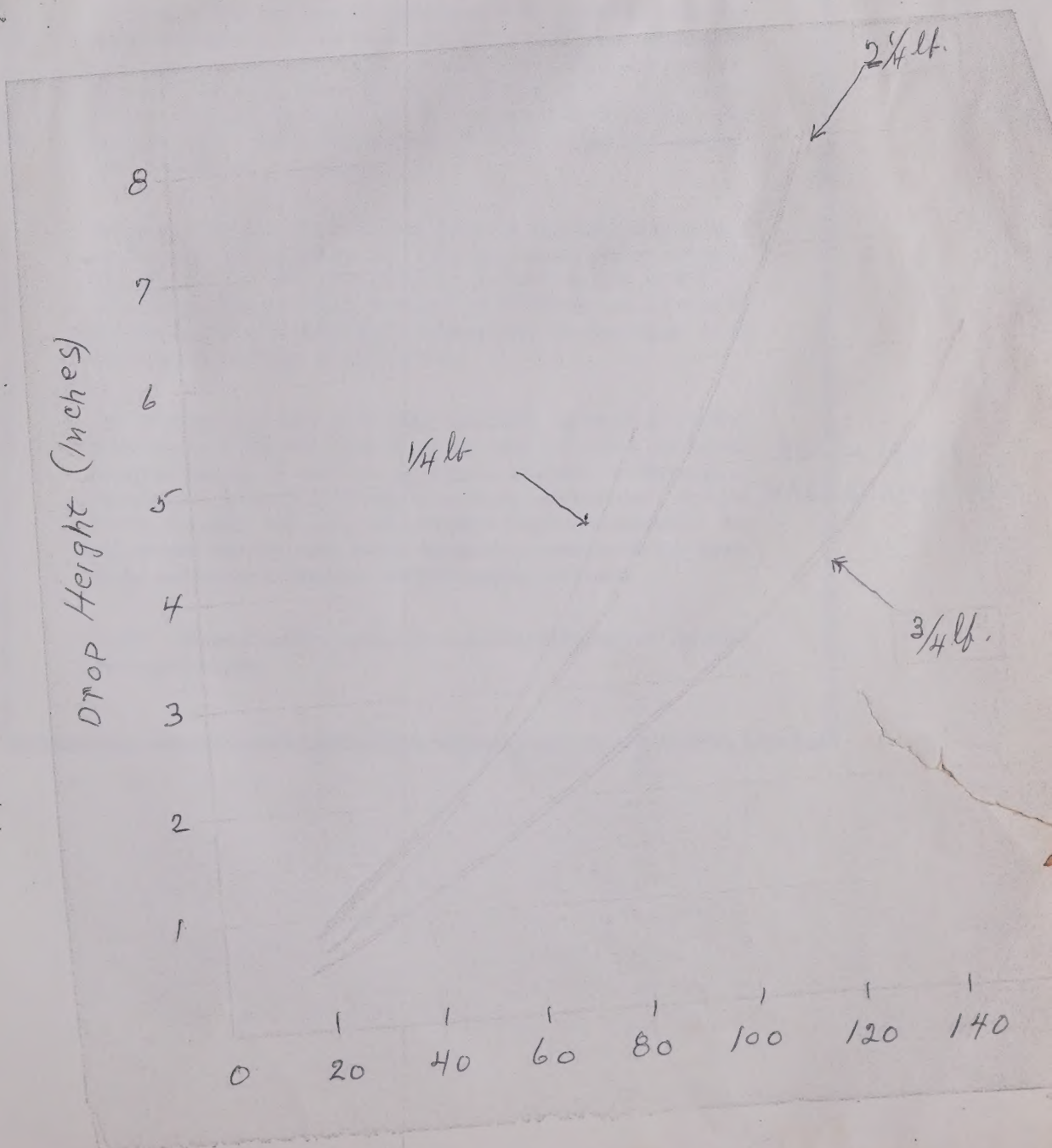
Figure 14. Schematic diagram of the Model 1W2A Capacitance Bridge.

# Parts List for Model 1[illegible] 2A Bridge

*NOTE. The Sprague Electric and Sprague Products catalog numbers that sometimes appea[illegible] in the "Description" column should not be confused with the Replacement Part Numbers. The Sprague Electric OEM and Sprague Products distributor stock catalog numbers are furnished to facilitate field repairs.*

| Circuit Symbol | Replacement Part. No. | Description |
|---|---|---|
| $C_1$ | 1-9015-162 | Capacitor, fixed, paper-film dielectric, metal-clad 0.1 $\mu$F, $\pm$10%, 600 Vdc, Sprague Products Type 91P10496S2 or MIL Type CP04A1EF104K. |
| $C_2$, $C_9$ | 1-9015-155 | Capacitor, fixed, electrolytic, aluminum, polar, 2$\mu$F, +100, –10%, 15 Vdc, Sprague Electric Type 30D159A1 or Sprague Products Type TE-1149. |
| $C_3$ $C_4$ $C_5$ | B1-9015-173B | Capacitor, fixed, electrolytic, aluminum, polar, 10 $\mu$F, +100, –10%, 6 Vdc, Sprague Electric Type 30D128A1, Sprague Products Type TE1087. |
| $C_7$, $C_{10}$, $C_{14}$ | 1-9015-156 | Capacitor, fixed, electrolytic, aluminum, polar, 10$\mu$F, +100, –10%, 25 Vdc, Sprague Electric Type 30D182A1 or Sprague Products Type TE-1204. |
| $C_6$, $C_8$, $C_{11}$, $C_{20}$ | 1-9015-157 | Capacitor, fixed, electrolytic, aluminum, polar, 100 $\mu$F, +100, –10%, 6 Vdc, Sprague Electric Type 30D135A1 or Sprague Products Type TE-1102. |
| $C_{12}$, $C_{13}$ | 1-9015-158 | Capacitor, fixed, electrolytic, aluminum, polar, 100 $\mu$F, +100, –10%, 15 Vdc, Sprague Electric Type 30D172A1 or Sprague Products Type TE-1162. |
| $C_{15}$, $C_{16}$ | 1-9015-159 | Capacitor, fixed, electrolytic, aluminum, polar, 100 $\mu$F, +100, –10%, 25 Vdc, Sprague Electric Type 30D188A1 or Sprague Products Type TE-1211. |
| $C_{19}$ | 1-50-208A | Capacitor, fixed, polystyrene dielectric, metal-clad, 1.326 $\mu$F, $\pm$0.1%, 600 Vdc Sprague Electric Type 114P (Special). |
| $C_{21}$ | 1-9015-180 | Capacitor, fixed, mica dielectric, molded, .000027 $\mu$F, $\pm$5%, 500 Vdc, Sprague Products Type MS-472. |
| $C_{22}$ | 1-9015-132L | Capacitor, fixed, paper-film dielectric, metal-clad, .0008$\mu$F, $\pm$5%, 100Vdc, Sprague Electric Type 18S-4082. |
| $C_{23}$ | 1-9015-132M | Capacitor, fixed, paper-film dielectric, metal-clad, .008$\mu$F, $\pm$5%, 100Vdc, Sprague Electric Type 18S-4083. |
| $C_{24}$ | 1-9015-132N | Capacitor, fixed, paper-film dielectric, metal-clad, .08$\mu$F, $\pm$5%, 200Vdc, Sprague Electric Type 18S-4084. |
| $C_{25}$ | 1-9015-132P | Capacitor, fixed, paper-film dielectric, metal-clad, 0.8$\mu$F, $\pm$5%, 200Vdc, Sprague Electric Type 18S-4093. |
| $C_{26}$ | 1-9015-181 | Capacitor, fixed, electrolytic, solid tantalum, NP, 8$\mu$F, $\pm$5%, 20Vdc, Sprague Electric Type 151D805X50200. |
| $CR_1$, $CR_2$, $CR_3$, $CR_4$, $CR_5$, $CR_6$ | 1-88-52 | Diode, Type 1N91. |
| $CR_7$, $CR_8$, $CR_9$, $CR_{10}$ | 1-88-2 | Diode, Type 1N1695. |
| $DS_1$ | 1-217-56 | Lamp, pilot, neon. |
| $F_1$ | 1-44-32 | Fuse, 0.5A, type 3AG. |
| $FL_1$ | 11-9010-1C | Filter, 120 cps bandpass, Sprague Electric Type JW17-855 |
| $FL_2$ | 11-9010-1B | Filter, 60 cps bandpass, Sprague Electric Type JW17-886A. |
| $FL_3$ | 11-9010-4A | Filter, 120 cps bandpass, Sprague Electric Type JW17-1647A. |
| $J_1$ | 1-217-24 | Connector, male |
| $M_1$ | 1-9010-52 | Meter, 200 $\mu$A d-c |
| $Q_1$ | A1-9029-77 | Transistor, Type 2N535B |
| $Q_2$, $Q_3$, $Q_4$ | A1-9029-79 | Transistor, Type 2N417 |
| $R_1$ | 1-9012-A1603S | Resistor, fixed, composition, 47K ohms, $\pm$5%, 0.5 watt. |
| $R_2$, $R_6$, $R_8$, $R_{11}$ $R_{12}$, $R_{16}$, $R_{17}$ | 1-9012-A1603 | Resistor, fixed, composition, 10K ohms, $\pm$5%, 0.5 watt. |
| $R_3$, $R_5$, $R_{10}$, $R_{15}$ $R_{24}$, $R_{35}$ | 1-9012-A1604 | Resistor, fixed, composition, 100K ohms, $\pm$5%, 0.5 watt. |
| $R_7$ | C1-9012-A1602M | Resistor, fixed, composition, 3.3K ohms, $\pm$5%, 0.5 watt. |
| $R_9$, $R_{13}$, $R_{18}$, $R_{21}$ | 1-9012-A1602 | Resistor, fixed, composition, 1K ohm, $\pm$5%, 0.5 watt. |
| $R_{14}$ | 1-9012-A1602B | Resistor, fixed, composition, 1.2K ohms, $\pm$5%, 0.5 watt. |
| $R_{19}$ | C1-9012-A1602U | Resistor, fixed composition, 5.6K ohms, $\pm$5%, 0.5 watt. |
| $R_{20}$ | C1-9012-A1600Y | Resistor, fixed, composition, 82 ohms, $\pm$5%, 0.5 watt. |
| $R_{22}$ | 1-9010-22 | Resistor, continuously adjustable, 0-10K ohms, $\pm$20%, 0.5 watt. |
| $R_{23}$ | 1-9012-~~51~~ 48F | Resistor, fixed, wirewound, ~~1.5K~~ ohms, $\pm$5%, 10 watts, Sprague Products |
| $R_{25}$ | 1-9012-B55B | Resistor, fixed, wirewound, 132.6K ohms, $\pm$.05%, 1 watt, Sprague Electric Type 301E356 (special). |
| $R_{26}$ | 1-9012-B55A | Resistor, fixed, wirewound, 13.26K ohms, $\pm$.05%, 1 watt, Sprague Electric Type 301E355 (special). |
| $R_{27}$ | 1-9012-B55 | Resistor, fixed, wirewound, 1.326K ohms, $\pm$.05%, 1 watt, Sprague Electric Type 301E354 (special). |
| $R_{28}$ | 1-9012-B54A | Resistor, fixed, wirewound, 132.6 ohms, $\pm$0.1% 1 watt, Sprague Electric Type 301E353 (special). |
| $R_{29}$ | 1-9012-B54 | Resistor, fixed, wirewound, 13.26 ohms, $\pm$0.1%. 1 watt, Sprague Electric Type 301E352 (special), |
| $R_{30}$ | 1-9012-B53 | Resistor, fixed, wirewound, 1.326 ohms, $\pm$0.2%, 1 watt, Sprague Electric Type 301E348 (special). |
| $R_{31}$ | 1-9012-B52 | Resistor, fixed, wirewound, 0.1326 ohms, $\pm$0.5%, 1 watt, Sprague Electric Type 301E341 (special). |
| $R_{32}$ | 11-9012-1A | Resistor, adjustable, step decade, wirewound, 0-12K ohms, $\pm$.05%, 0.5 watt. |
| $R_{33}$ | 11-9012-1 | Resistor, adjustable, step decade, wirewound, 0-1.2K ohms, $\pm$.05%, 0.5 watt. |
| $R_{34}$ | C1-9012-A1603T | Resistor, fixed, composition, 51K ohms, $\pm$5%, 0.5 watt. |
| $R_{36}$ | C1-9012-A1603X | Resistor, fixed, composition, 75K ohms, $\pm$5%, 0.5 watt. |
| $S_1$ | 1-41-8 | Switch, toggle, SPST |
| $S_2$ | 1-41-11 | Switch, rotary, DP7T |
| $S_3$ | 1-217-41 | Switch, rotary, 6P3T. |
| $T_1$ | 1-9010-29 | Transformer, power (special) |
| $T_2$ | 1-9010-30 | Transformer, bridge (special) |
| $Z_1$, $Z_2$ | 1-88-53 | Diode, Type IN751 |

# NOTES


2¼ lb.
1/4 lb
3/4 lb.
Drop Height (Inches)
8
7
6
5
4
3
2
1
0
20
40
60
80
100
120
140

# Warranty

The Sprague Electric Company warrants each new instrument manufactured by Sprague to be free from defects in material and workmanship, and to perform according to applicable specifications, if properly operated, for a period of one year from the date of original purchase. The Sprague Electric Company's liability is limited to service work performed at the Sprague factory. Specifically excluded from this Warranty are transistors, tubes, bulbs, fuses, and batteries.

Before this Warranty is effective, the following conditions must be met: (1) The warranty registration card must have been returned within 30 days after the date of original purchase, (2) The instrument must be returned to the Sprague Electric Company, (3) Subsequent examination by Sprague must disclose in Sprague's judgment that the instrument is defective within the terms of this Warranty.

This Warranty is in lieu of all other warranties, expressed or implied. If the return of this instrument is deemed necessary, advise the Special Products Division of the Sprague Electric Company in ~~Bennington, Vermont,~~ NORTH ADAMS, MASSACHUSETTS giving full details, including model and serial number. Sprague Electric Company will reply with complete shipping instructions. **No adjustments will be made unless Sprague's permission for the return of the instrument is obtained BEFORE making shipment.**

*NOTE. Returned instruments must be packed carefully, marked "Fragile," and shipped prepaid.*

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